

GRAPHEME DISCRIMINATION TRAINING  
IN CHILDREN PREDICTED TO DEVELOP READING DIFFICULTIES

By

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The total population of kindergarten children at an urban elementary school was administered a behavioral screening battery designed to identify potentially poor and superior readers. Twenty-four children whom the battery predicted would develop severe reading problems were randomly divided into experimental ( $N=7$ ), treated comparison ( $N=6$ ), and untreated control ( $N=11$ ) groups. All subjects were administered a paper-and-pencil match-to-sample letter discrimination pretest. The experimental and comparison groups were also administered a match-to-sample test on the training apparatus. The experimental group was then given 6 weeks of faded distinctive feature discrimination training. The comparison group was given 6 weeks of traditional multiple

feature discrimination training. The control group received only regular classroom experience.

Following training, the treatment groups were readministered the match-to-sample test on the training apparatus. All three groups were also readministered the paper-and-pencil match-to-sample test. The treatment groups were then given 8 weeks of grapheme-phoneme training by another experimenter. Three months after the original letter discrimination training, all subjects were readministered the paper-and-pencil match-to-sample test. The Beery Developmental Test of Visual-Motor Integration was also administered, and teacher ratings of each subject's classroom performance were obtained. The paper-and-pencil match-to-sample test was administered a fourth time one year after the original letter discrimination training. The Beery Test of Visual-Motor Integration was readministered at this time and teacher ratings of each child's classroom performance were again obtained. Two additional measures, tests of word matching and word recognition, were also administered one year after the discrimination training. The teacher ratings were used as criterion measures to eliminate false positive subjects from the data analysis.

One purpose of the experiment was to evaluate the effectiveness of two methods of letter discrimination training with children predicted to develop severe reading difficulties. No significant differences were present between groups on any of the match-to-sample discrimination tests. It was concluded that

neither method of discrimination training was more effective than regular classroom teaching in improving letter discrimination performance. Another purpose of the experiment was to evaluate the combined effect of grapheme discrimination and grapheme-phoneme training on more general reading related performances. No significant differences were present between groups on teacher ratings of classroom performance or on the word matching and word recognition tests with one exception: significantly more treatment than control children were rated by their teachers as able to recognize most of the letters of the alphabet. Treatment children were also found to have performed significantly better than control children on the Beery Test of Visual-Motor Integration. This difference between groups on the Beery, however, was not present 9 months after the termination of training. It was concluded that grapheme discrimination training combined with grapheme-phoneme training was no more effective than regular classroom teaching in generally improving reading related skills. The combined training did appear to be more effective than regular classroom teaching in improving alphabet recognition and visual-motor performance, two skills which involve visual discrimination.

# I

## INTRODUCTION

READING IS THE MOST BASIC and important of all skills taught in American schools; yet 25% of school children in the United States are reading below grade level (Gibson & Levin, 1975) and 15% are considered to exhibit severe reading disabilities (Kline, 1972). In the past, much research has focused on improving these children's reading skills. Vernon (1960, p. 184) characterized this research as containing numerous enthusiastic recommendations, but few controlled studies demonstrating actual improvement. The failure to develop successful remediation techniques has contributed to the recent trend toward preventive research. Such research has generally focused on prereading skills in children. Much of it has dealt with the training of visual perceptual processes. Hammill (1972) found that in 21 of 25 such studies, improvement in reading could not be expected as a result of systematic visual-motor training. He ascertained from his survey that "little correlation existed between measures of visual perception and tests of reading comprehension and that training visual perceptual skills, using currently available programs,

has no positive effect on reading and possibly none on visual perception" (p. 552).

At present it seems that the most effective early intervention techniques must lie in the manipulation of the reading process itself. The problem with this approach is that it requires an accurate conception of the reading process and of the skills necessary to master the process. Gibson (1965) presented such a conceptual framework supported by a number of relevant empirical studies. She distinguished three sequential phases in the process of learning to read: (1) learning to differentiate written symbols, (2) learning to relate letters to sounds, and (3) learning to utilize progressively higher-order units of linguistic structure, i.e. spelling and morphemic patterns in letter sequences, and syntactic and semantic patterns in word sequences. The phases are organized such that each earlier phase must be mastered before the succeeding, more complex phases can be successfully undertaken. It would seem that an adequate intervention technique must insure that each preceding phase is mastered before attempting to focus on a later stage.

#### PREDICTION OF READING PERFORMANCE

The first step, however, in developing a preventive intervention program for children destined to be poor readers is to accurately identify these children. Without valid identification of the target sample, the effects of early intervention cannot



be determined. A behavioral screening battery has recently been developed which is designed to detect children who will later become severely disabled readers (Satz, Friel & Rudegear, 1975). The screening battery was standardized on the total population of white male kindergarten children ( $N=497$ ) in Alachua County, Florida, schools in 1970. The battery was later validated against independent reading criteria at the end of first, second, and third grade. An independent crossvalidation study was undertaken in 1971, based on a sample of white male kindergarten children ( $N=181$ ) in five Alachua County schools. Their reading performance was assessed at the end of second grade. These studies revealed that the battery consistently identified over 90% of the children destined to become severely disabled readers.

A second crossvalidation study was initiated in September 1974 and included the total population of kindergarten children ( $N=132$ ) in one Gainesville, Florida, elementary school. Only achievement ratings taken at the end of kindergarten are available, and this data must be considered highly tentative. These results, however, indicate that the battery successfully predicted 100% of the children who were rated as severely learning disabled at the end of kindergarten (Satz & Friel, 1976).

This degree of predictive accuracy allows for the development of preventive programs with children destined to become severely disabled readers. The advantages of early intervention are twofold: remediation can be undertaken before the child has

suffered the damaging effects of continuous academic failure and also at a time when the central nervous system may be more pliant and responsive to change. Indeed, Keeney and Keeney (cited in Strag, 1972) found that when a diagnosis of dyslexia was made during first and second grade, 82% of these students could be brought up to grade level, while only 46% of children identified in third grade and 10-15% of children identified in fifth through seventh grades could be brought up to grade level. Bloom (1964) has shown that environmental manipulations have their greatest quantitative effect on a behavior at its most rapid period of change.

The present study has attempted to identify "high risk" kindergarten children before they have begun to develop reading problems and has focused on one skill, differentiation of letters, which develops rapidly at this age.

#### DISTINCTIVE FEATURES

The next step in developing an intervention program based upon Gibson's model is to design an effective program for training children to differentiate written symbols. Once this is successfully accomplished, each succeeding skill can be integrated into a comprehensive program. Two questions arise at this point: What does the child learn when he succeeds in discriminating letters and how can this most effectively be taught?

Lavine (cited in Gibson & Levin, 1975) investigated whether children between the ages of 3 and 6.5 who had not yet been taught to read could differentiate writing from pictures. She found that 3-year-old children distinguish between graphic displays of objects and letters, even though they may be unable to name the letter or word and even though they have not been previously exposed to the particular graphic system (Hebrew for example). Furthermore, although multiple versus single units, linear versus nonlinear arrangements, and repetitive versus non-repetitive units contributed to the differentiation of writing from pictures, the most important information appeared to be the features of the letters themselves. Over 87% of 3-, 4-, and 5-year-old children identified Roman, cursive, and Hebrew characters as writing. A small percentage of children identified Mayan designs and Chinese characters as writing. This percentage decreased from age 3 to 4, then increased slightly at age 5. A high percentage of children identified artificial letterlike characters as writing. This percentage remained the same at ages 3 and 4, but decreased at age 5. These data suggest that children who could not yet read demonstrated an increasing sensitivity to familiar features of real letters. Gibson and Levin concluded that the children have learned a set of internal features common to the letters of their written system, even though the children have not yet learned to recognize individual shapes. They cited the absence of a difference in responses to Roman and Hebrew script as support for this conclusion.

Davidson (1935) was the first to systematically study confusion errors in letter discrimination. She gave kindergarten and first-grade children a letter matching test. A larger percentage of kindergarten than first-grade children made every type of error. Practically all kindergarten children and a smaller but substantial number of first graders made reversal errors. There was a marked and consistent decrease in the percentage of children making errors with an increase in mental age. Between the mental ages of 5.5 and 6 years there was a marked decrease in the percentage of children making reversal and inversion errors. The greatest decrease in reversal errors occurred at an age of 7.5 years. Davidson concluded that some letters of the alphabet are more difficult to discriminate than others. Reversals are most difficult with inversions closely following. It seems that children pass through certain stages before they are able to distinguish *b* from *d* and *p* from *q*. In the first stage all letters are confused. In the second stage only reversals are confused. The third stage is marked by the ability to recognize that reversals are directionally different, but without considering the letters as different. The final stage includes the recognition that reversals are different letters.

Gibson, Gibson, Pick, and Osser (1962) hypothesized that there are certain critical dimensions of difference, such as break versus close, straight versus curve, rotations, and reversals, which are the features initially utilized in

discriminating letters. They studied the development of ability to discriminate letterlike forms, in children 4 through 8 years of age, by requiring the child to select figures identical to a standard figure from an array of copies and transformations of the standard. The mean errors for each type of transformation were determined, and it was found that discrimination of the letterlike forms improved with age, as expected, but the slopes of the error curves were different, depending on the transformation to be discriminated. Thus, some transformations are harder to discriminate than others, and improvement occurs at different rates for the various transformations. Errors for circle versus break transformations were relatively few, even in the youngest subjects, and declined to almost zero in the 8-year-old children. Errors for rotations and reversals started high, but dropped to nearly zero by 8 years. Errors for changes of line-to-curve were relatively great at 4 years of age, but by 8 years had declined almost to zero. The slopes of the curves indicate that the greatest developmental change between 4 and 8 years is in confusion of rotation-reversals, with line-to-curve errors showing the next greatest drop and break versus close errors, the least.

This experiment was replicated with real letters and the same transformations on the 5-year-old group. Errors were fewer for letters, but the correlations between transformations were significant in every case. The correlation between the confusions

of the same transformations for real letters and for the letter-like forms was very high ( $r=+0.87$ ). Gibson et al. hypothesized that "it is the distinctive features of grapheme patterns which are responded to in the discrimination of letterlike forms. The improvement in such discrimination from four to eight is the result of learning to detect these invariants and of becoming more sensitive to them" (p. 904).

Gibson, Osser, Schiff, and Smith (1963) investigated the dimensions of difference a child must learn to detect in order to perceive each letter as unique. They began by intuitively constructing a list of the distinctive features of letters, such that a unique pattern of features characterized each letter. Their list of 12 features included verticality, horizontality, diagonality, curvature, openness or closure, intersection, cyclic change, symmetry, and discontinuity. They obtained a confusion matrix of the 26 Roman capital letters, based on the errors of 4-year-old children who made matching judgments of letters, and compared the errors in the confusion matrix with those predicted by the feature chart. If the features were correctly chosen, the subjects should have confused most frequently those letters having the smallest number of feature differences. The results yielded 12 of 26 positive significant correlations. Considering that the features were not weighted, one can see that the prediction from this feature list was fairly good. A multidimensional analysis of the matrix corroborated

the choice of curve versus straight-and-obliqueness variables, suggesting that these features have priority in the discrimination of letters.

Gibson, Schapiro, and Yonas (1968) obtained confusion matrices for two sets of nine artificial graphemes. Adults and 7-year-old children were asked to make same/different judgments. Error and latency measures proved to be highly correlated and revealed an identical structure. The adult subjects' data for the nine characters paired in all combinations indicated that the first split separated letters of diagonality from all the others. Next, the round letters were split off from the others, and finally, the square right-angular letters were split off from letters characterized by curvature. The children showed a similar but not identical pattern. First, the letters were split along the curve versus straight dimension. Next, the round letters were differentiated from those characterized by only a curve. Finally, the straight horizontal-vertical letters were split off from those with diagonality. The authors concluded that these results confirm the hypothesis that letters are distinguished from one another by way of distinctive features that are shared to varying degrees by different pairs of letters.

Popp (1964) used a match-to-sample paradigm to determine which pairs of lower-case letters are most often confused by kindergarten children. Her results further substantiate the data of Gibson et al. (1968). Popp found that most confusions

arise from rotations and reversals and relatively few from close-versus-break transformations. She concluded that "consideration of the distinctive features and of the formal similarity of letters should provide insight for training a specific skill in visual discrimination for letters. Remaining as a matter for further research is the problem of determining whether children trained to discriminate highly confusable letters on the basis of distinctive features and/or formal similarity will then be able to accurately discriminate all letters, and whether such training will have any effect on their later reading achievement" (p. 225).

Dunn-Rankin (1968) analyzed letter similarity, using a relative discrimination task rather than an absolute discrimination task. Using lower-case letters he asked second and third graders to indicate which of two letters was most similar to a target letter, under the assumption that the letter combinations judged most similar would be most likely to be confused. The results generally supported the finding that rotational errors in all three spatial planes are likely sources of confusion. Factor analysis revealed that the letters may be clustered together in groups based upon size, formal similarity, axial rotation, and topological line-to-curve transformations. The first factor contrasted the short curved letters (*e, a, s, c, o*) with the tall straight-line letters (*f, l, t, k, i, h*). The second factor consists of *p, d*, and *b* with *o, g*, and *h* partially loading in



contrast to *w*. The third factor contains the partially curved short letters *n*, *u*, *m*, and *w*, with *h* partially loading on this factor. The fourth and fifth factors appear to be *x* and *y* respectively. Dunn-Rankin suggested that within clusters the particular features of letters become increasingly important for discrimination. He concluded that "a suggested principle of learning is to present materials that offer the opportunity for maximum contrasts before moving to items with minimal cues for discrimination" (p. 994).

Some of Dunn-Rankin's data suggest that letters with greater common area may be more confusing than letter pairs with less area in common. Dunn-Rankin, Leton, and Shelton (1968) developed an index based upon the ratio of common area to independent area in order to determine the congruency of lower-case letters. The congruency matrix was factor analyzed. Five factors composed of letter groups were identified. Factor I (*p*, *b*, *d*, *q*) shows structural similarities which are a combination of straight-line and closed-curve features. The letter congruencies in this factor are due to rotations in all three planes. Factor II (*i*, *f*, *l*, *j*, *t*) contains letters characterized by a straight line and secondarily open-curve features. The letter congruencies in this factor are based on all three rotations. Factor III (*y*, *v*, *x*, *w*, *z*, *k*, *g*) shows a structural relationship of the letters because of line and slant features which result in acute angles. Factor IV (*n*, *u*, *m*, *h*) contains letters characterized by

short, straight-line, and extended-curve features. The *n-u* congruence in this factor is effected by axial rotation in depth. Factor V (*e, c, o, s, a*) is characterized by open- or closed-curve features and a similarity in height.

Given that the child learns to discriminate graphemes by detecting their distinctive features, it can then be asked how this type of discrimination develops. Pick (1965) designed an experiment to evaluate two hypotheses about improvement in discrimination. The first is called the schema hypothesis and supposes that the child constructs a model or memory image of each letter by repeated experience of visual presentations of the letter. Discrimination occurs by matching sensory experience to a previously stored concept or model. The second, which is called the distinctive feature hypothesis, proposes that the child learns by discovering how forms differ and then transfers this abstract knowledge to new letterlike forms. Practice enables the subject to discover which of a number of stimulus variables are critical in that they serve to distinguish between one object and another.

To test these hypotheses, Pick trained a group of kindergarten children to discriminate letterlike forms (Stage 1). The subjects were then divided into three groups. Group I was given sets of stimuli to discriminate which varied in new dimensions from the same standards discriminated in Stage 1. Group II was given new standards, but the same dimensions as

discriminated in Stage I. Group III received both new standards and new dimensions of difference to discriminate (Stage 2). Thus, Group I had the same prototypes as those that they learned in Stage 1, while Group II had the same dimensions as those that they learned to discriminate in Stage 1. The mean number of errors made during Stage 2 was computed for each group. The results indicated that Groups I and II performed significantly better than Group III but that Group II, the group with the familiar transformations and new standards, performed significantly better than Group I, which had received new transformations of old standards.

These results suggest that while children do learn the prototypes of letter shapes, the prototypes themselves are not the original basis for differentiation. Learning distinctive features appears to be a significant component of improvement in visual discrimination of letterlike forms.

A second experiment involved a tactual discrimination task of successive comparison. The prototype and distinctive feature groups made an equal number of errors on the transfer task but did significantly better than the control groups.

A third experiment required a tactual discrimination task with simultaneous comparison. The prototype and control groups did not differ in mean number of errors, but the distinctive feature group performed significantly better than both. These results suggest that the superior group learned the distinctive

features of the forms since they had no opportunity to construct prototypes of the forms used in the transfer task. The groups which could use prototypes in the transfer task performed no better than the control group.

In summary, the children who could use what they had learned about distinctive features showed the best transfer task performance. Those who could use schemata also showed transfer, but significantly less than the distinctive feature group. These results may be interpreted as suggesting that the detection of distinctive features will always facilitate improvement in discrimination but that under conditions of successive comparison prototype construction will independently facilitate such improvement. A more parsimonious interpretation is that the detection of distinctive features may lay the basis for improvement in discrimination. Only when such detection is dependent on memory does prototype learning occur. In other words, the detection of distinctive features may be the necessary and sufficient condition for improvement in discrimination.

Williams (1969) trained kindergarten children to discriminate letterlike forms. Her experiment compared three conditions: (1) discrimination training where the comparison stimuli were quite different from the standard, (2) discrimination training where the comparison stimuli were transformations (rotations and reversals) of the standards, and (3) reproduction training involving tracing and copying of the standards. A delayed

match-to-sample task was used because it approximates the perceptual learning tasks involved in actual reading, more closely than does simple discrimination training. The results indicated that discrimination training in which the comparison stimuli were transformations was superior to discrimination training where the comparison stimuli were totally different forms. This suggests that comparisons involving minimally different stimuli forced the subject to attend to and abstract more attributes of the standard, which were then used for new test comparisons. Reproduction training was not as effective as discrimination of transformations but was as effective as simple discrimination training.

Williams summarizes her study:

The crucial point is that even after a small amount of training at an appropriate level (i.e., the beginning of the kindergarten year), there were significant differences among the training groups. These data indicate clearly that the effectiveness of readiness training does indeed depend on the particular technique used, and that there would be wide variation in the effectiveness of typically used readiness materials. While special practice is often given on rotation and reversals, usually too much time is devoted to copying and tracing or to discrimination exercises that, according to this data, are relatively ineffective. Moreover, such systematic training is sometimes given only in remedial work, that is, after a child has already developed some difficulty. The present experiment suggests (1) that more time be devoted to

discrimination training that involves comparison of letters with their transformations and (2) that this type of training be given early. It is quite effective at the very start of kindergarten, and obviously, if the occurrence of certain relatively common perceptual confusions could be minimized by appropriate training techniques introduced in the beginning stages of instruction, there should be less necessity later for remedial techniques.

(p. 513)

It was decided that an intervention program aimed at the first stage of the reading process--the differentiation of written symbols--would be most effective if it trained children to respond to the distinctive features of letters. Gibson (1970) stated that "methods of teaching that would promote efficient strategies of perceptual search and detection of invariant order should be a first concern in instructional programs" (p. 143). Guralnick (1972), in a review of alphabet discrimination and distinctive features, suggested that "a training program specifically designed to teach children to attend to these features should be valuable in increasing discrimination skills and, eventually, naming of letters in the alphabet" (p. 430).

#### DISCRIMINATION TRAINING

The last step in developing an intervention program based upon Gibson's model and incorporating the findings presented in the previous section is to determine the most effective procedure

for training children to respond to the distinctive features of letters. Terrace (1963) was the first to describe "errorless discrimination training." He taught pigeons to discriminate colors by gradually equalizing brightness and duration differences between correct and incorrect responses. He superimposed vertical and horizontal stripes over the colors, and the colors were gradually faded out. Both the color discrimination and the more difficult stripe discrimination were acquired without errors. The major finding was that while differential reinforcement in the presence of two stimuli is a necessary condition for establishing a discrimination; the occurrence of errors is not necessary. Furthermore, in comparing the performance of pigeons following discrimination training with and without errors, it was found that the pigeons trained with errors exhibited a relatively poorer discrimination performance once the discrimination was acquired. These pigeons tended to produce bursts of errors and to exhibit "emotional" responses such as wing flapping and turning away from the response key following incorrect responses.

Several other studies have demonstrated that fading (errorless discrimination) is more effective than simple trial and error methods. Hively (1962) was the first to report the training of children in a faded series of progressively difficult discrimination tasks, eventuating in a match-to-sample paradigm. This program was composed of four series: (1) no

incorrect response was available and the matching stimulus was placed directly below the sample stimulus, (2) both choice stimuli were presented still in the same positions, with the correct choice always located directly below the sample stimulus, (3) the sample stimulus was placed in the middle, although the choice stimuli still remained in fixed position, and (4) the position of the choice stimuli was varied from trial to trial. Thus, the child advanced from an easy discrimination in which no incorrect choice was available to a discrimination in which no cues were available except those provided by the stimuli themselves. Reinforcement was simply the presentation of the next set of stimuli.

The results confirmed the hypothesis that learning is more efficiently accomplished when the subject is trained in a progressively more difficult discrimination than when training is given in the final discrimination alone. The errors the subjects made were a function of the size of the steps in the program and the length of training on each discrimination. Thus, these programs can be too long as well as too short or discontinuous. The more errors the training procedure allowed the children to make, the more they tended to go on making.

Moore and Goldiamond (1964) presented preschool children with a delayed match-to-sample task in which subjects were required to match one of three triangles varying in orientation with that of its previously presented sample. This discrimination proved



difficult for preschool children. However, when only the correct match was illuminated, discrimination was easily established. The brightness difference between correct and incorrect matches was gradually faded out until all stimuli were of equal brightness. The discrimination was maintained in the absence of the brightness difference, thus transferring stimulus control from brightness to form with virtually no errors.

In an experiment with similar results, Touchette (1968) compared methods of teaching severely retarded boys to determine the position of a black square and to press the nearest key to it. Of seven boys given trial and error learning, one learned the task. The six boys who failed to learn were presented with a program of gradual stimulus change, and all but one acquired the performance. The child who did not was under stimulus control during the program but reverted to a position-based response learned during trial and error training when he reached the criterion stimuli. Six similar children were presented with graduated stimulus training only, and all six learned the criterion discrimination with few or no errors. Both groups were tested for retention of the criterion performance 35 days after the completion of training. Two boys with previous trial and error training showed no signs of retention after 35 days.

Touchette observed that retardates form superstitions early in discrimination training which frequently seem to prevent the development of an appropriate controlling relation. The occurrence

of spurious controlling relations cannot be avoided in a trial and error procedure. If training is initiated by reinforcing a stimulus-response relation which already exists, or can be easily established, it is then possible to gradually shift the stimuli toward those which comprise the criterion discrimination while maintaining control of responses by specified aspects of the training situation.

Sidman and Stoddard (1967) utilized a fading procedure to teach severely retarded boys a circle-ellipse form discrimination. They compared subjects trained on the fading program with subjects trained by trial and error. Their procedure involved transferring stimulus control from a simple brightness discrimination to a form/no-form discrimination and, finally, to a circle-ellipse discrimination. This was accomplished by fading out the brightness dimension, leaving a form/no-form discrimination. Finally, the alternative form was gradually faded in to achieve the circle versus ellipse discrimination. Correct choices were reinforced by chimes, candy, and the next slide. A correction procedure was used so that following a wrong choice, the stimuli remained until a correct choice was made. A back-up procedure was also used in which a correct response following an error caused the slide tray to reverse, thus presenting the preceding slide. Sidman and Stoddard found that the children taught by the fading procedure performed much more effectively than did the group trained by trial and error.

Bijou (1968) developed a fading program to teach normal children 3.5 to 6.9 years of age and retarded children 3.9 to 8.9 years of mental age to make form discriminations, mirror-image discriminations, and rotated mirror-image discriminations. Mirror-image discrimination was based on fading in, by construction, of the mirror images of three forms: a flag, square Z, and winged L. A five-choice match-to-sample paradigm was used. A correct choice resulted in a light, chime, and appearance of the next sample. The next set of choices was produced by pressing on the sample window. An incorrect choice was followed by blackout of the stimulus array, which could be restored by pressing on the sample window. A back-up procedure insured that an incorrect response followed by a correct response produced the preceding rather than succeeding stimulus array. The results indicated that the training program was effective in teaching both normal children and retardates the orientation discrimination. The retarded children did well in discriminating rotated forms but had more difficulty with rotated mirror-image discriminations. Success was approximately proportional to mental age.

A modified program was established, consisting of only the flag form, the mirror-image of which was faded in by manipulating its size. Training began with the nonrotated mirror-image form and advanced to training with rotated mirror-image forms. A correct response was followed by a colored bead, light, chime, and appearance of the next sample, while an incorrect response

was followed by a brief buzz and blackout of the choices, which reappeared upon pressing the sample window. This sequence was repeated with each incorrect response until a correct response occurred. The back-up contingency was eliminated. After an error, reinforcement for a correct response was a chime, light, and forward movement of the program, but no bead. At the end of the session, the children were allowed to exchange beads for toys, candy, or pennies on a ratio basis. It was concluded that although the fading technique using the flag form required improvement, the fading technique has proven to be by far the most promising for the development of left-right concepts.

Two additional findings are worth noting. Bijou found that having subjects repeat a set will not improve their performance. Repetition of sets resulted in the same number of errors concentrated around the same stimuli. Pretests and posttests--composed of forms used in training, new forms, and letters of the alphabet--indicated that the training experience facilitated mirror-image discrimination of the new forms and of the alphabet letters. In the absence of data concerning the stimulus dimensions to be manipulated in fading, Bijou suggested that the part of the form which includes the clue essential to the discrimination be varied. This most closely approximates the goal of bringing the subjects' attending behavior under the control of that aspect of the stimulus which will be reinforced.

Several recent letter discrimination studies have focused upon the effects of emphasizing essential versus nonessential features in establishing letter discriminations. Using a match-to-sample visual discrimination task, Egeland, Braggins, and Powalski (1973) compared three methods of teaching 4- and 5-year-old children to discriminate letters. One group of subjects was taught by using the traditional reinforcement-extinction (trial and error) approach. A second group received errorless discrimination training with the faded cue highlighting the distinctive feature of the letter to be discriminated. A third group received errorless discrimination training with a feature irrelevant to the discrimination highlighted. The relevant cue group made significantly fewer errors on posttests than did the irrelevant cue and reinforcement-extinction group. These results suggest that the effectiveness of errorless discrimination training depends on whether the faded cue highlights a relevant or irrelevant dimension of the letter to be discriminated. Egeland et al. concluded that errorless discrimination training has educational value for young children who are having difficulty learning to discriminate letters or words, particularly where the child's difficulty is related to his failure to attend to the relevant dimension of the discriminative stimulus. He further suggested that intervention using an errorless discrimination technique to highlight the relevant distinctive features of letters offers a promising solution to this problem at the preschool and kindergarten level.

Using a match-to-sample letter discrimination task, Tawney (1972) also investigated the relative effects of training children to respond to critical and noncritical features of letterlike stimuli. Four-year-old children were divided into three groups (relevant feature, nonrelevant feature, and no-treatment control) based upon their performance in a letter discrimination pretest. The two experimental groups were then trained to respond to either "critical" or "noncritical" features of letterlike forms. All subjects were then posttested. While all groups made fewer errors on the posttest, mean error scores for the critical-feature group were significantly lower than those for the noncritical-feature group. Furthermore, the noncritical-feature group scores were not significantly different from the control group. Both treatment groups, however, showed a reduction in the kinds of confusion errors relative to the control group, although the effect was more powerful in the critical-feature group. Tawney's results suggest that critical-feature training was effective in reducing both the frequency and kinds of confusion errors, while the noncritical feature group was effective in reducing only the kinds of confusion errors. He suggested that future discrimination programs might include a fading procedure and utilize actual letter stimuli.

#### SUMMARY

In developing a preventive program for children who will later become poor readers, it is first necessary to accurately

identify those children destined to have severe reading difficulties. Once these children have been identified, a program designed to teach the essential skills of reading, starting with the developmentally earlier skills and continuing sequentially to the increasingly complex skills, could be implemented. Eleanor Gibson's analysis of the reading process provides an empirically supported developmental model of the processes involved in learning to read.

The first step in developing an intervention program based upon Gibson's analysis of the reading process is to design an effective program for training children to differentiate written symbols. Literature was cited which supports the proposition that letters are discriminated on the basis of their distinctive features and that the utilization of such features is a necessary and sufficient condition for the discrimination of letters. Although work on the analysis of the distinctive features of graphic forms is not complete, four types of features seem fairly well established. These are (1) break versus close, (2) curve versus straight, (3) relative diagonality, and (4) rotations and reversals. The most effective means of training for letter discrimination appears to be a program which teaches the child to discriminate critical features rather than actual letters. Such a program would use a fading procedure in which differences between forms would be exaggerated and gradually minimized while maintaining correct discrimination performance.

Research on form discrimination and orientation discrimination has shown that an effective training program must enable the child to respond to the relevant stimulus dimension which requires that errors in training be minimized, since the occurrence of errors indicated that the subject has learned to respond to irrelevant stimulus characteristics which become highly resistant to change. By presenting a particular feature in a variety of forms, the subject receives practice in scanning forms and detecting the essential feature. A number of different examples also allow a "learning set" or "concept" of the critical feature to be established. The present experiment is an attempt to incorporate these principles into a program for training "high risk" children to discriminate letters.

#### HYPOTHESES

HYPOTHESIS I. Discrimination training emphasizing the distinctive features of letters would be more effective than traditional letter discrimination training without emphasis on distinctive features. Specifically, the experimental group would make fewer errors on the "machine" posttest than the comparison group.

HYPOTHESIS II. Transfer from the training apparatus to printed material would be greater following distinctive feature training than letter discrimination training. Furthermore, both types of training would result in greater improvement in letter



discrimination than would normal classroom experience alone. Specifically, the experimental group would make fewer confusions and more correct responses than the comparison group, which in turn would make fewer confusions and more correct responses than the untreated control group on the paper-and-pencil match-to-sample test.

HYPOTHESIS III. The improvements predicted in Hypothesis II to follow treatment would continue to be present 3 months after training had ended. Specifically, the experimental group would continue to make fewer errors and more correct responses than the comparison group, which in turn would make fewer errors and more correct responses than the control group on the paper-and-pencil match-to-sample test.

HYPOTHESIS IV. At the end of kindergarten, children who received treatment would be rated by their teachers as performing better academically than control children. Specifically, the treatment group would be rated higher on scales of overall achievement, ability to recite, recognize and print the alphabet, ability to print own name, and ability to attend adequately. Fewer treatment than control children would be predicted to develop a reading problem.

HYPOTHESIS V. The improvements in letter discrimination predicted in Hypothesis II to follow treatment would continue to be present one year after the termination of training. Specifically, the experimental group would continue to make fewer errors and

more correct responses than the comparison group, which in turn would make fewer errors and more correct responses than the control group on the paper-and-pencil match-to-sample test.

HYPOTHESIS VI. Children in the treatment group would perform better than control children on a word matching test one year following letter discrimination training.

HYPOTHESIS VII. Children in the treatment group would perform better than control children on a word recognition test one year following letter discrimination training.

HYPOTHESIS VIII. Children in the treatment group would be rated by their teachers as performing better academically than control children one year after letter discrimination training. Specifically, treatment children would be rated higher on a scale of overall achievement than would control children, and fewer treatment than control children would be diagnosed as having a reading problem.

## II METHOD

### SUBJECTS

All of the kindergarten children at Stephen Foster Elementary School ( $N=132$ ) were screened at the beginning of the school year (September 1974) using the Satz and Friel abbreviated battery. Forty-four of these children were classified as high risk for severe reading difficulties. Under a prior agreement with the school, these 44 children were randomly assigned to one of three groups. A special education group to be treated by school personnel received 13 subjects. This group is unrelated to the experiment reported in this paper and will not be considered further. The 31 remaining children were assigned to a treatment group ( $N=16$ ) and an untreated control group ( $N=15$ ). Seven of these children left the school prior to the completion of training, leaving a treatment group of 13 subjects and a control group of 11 subjects. The treatment group was further divided into an experimental training group ( $N=7$ ) and a treated comparison group ( $N=6$ ).

The mean age for the 24 children at the beginning of training was 5 years 3 months, with a range from 4 years 10 months to 6 years 9 months. Seventeen of the children were males and

seven were females. The treatment group was composed of nine males and four females, while the untreated control group contained eight males and three females. Thirteen of the children were black and 11 were white. The treatment group was composed of seven blacks and six whites, while the untreated control group contained six blacks and five whites. These children were distributed across five kindergarten classes with no more than three children from any group in a particular class.

An additional group of 12 children classified as potential superior readers was used as a comparison group on the pretest. These children had a mean age of 5 years 7 months, with a range from 4 years 11 months to 5 years 11 months. Half of these children were male and half were female; all were white.

## APPARATUS

The training stimuli were two series of 884 slides of letter-like forms in a match-to-sample format. A BRS Foringer Human Test Console with an internally mounted Kodak Carousel projector and M&M dispenser was used to present the training stimuli. The Human Test Console is a large boxlike structure with a slanted front. A 3-by-5-inch rear projection screen was mounted in the center of the front panel. The screen was divided into three equal-sized panels sensitive to compression. A smaller compressible panel was located to the left of the projection panel. The M&M dispenser fed into a stainless steel tray positioned in

the lower center portion of the test console. A clear removable plastic guard was mounted over the tray to limit access to it. A small light and buzzer were positioned over the tray. This equipment was controlled by a portable BRS Foringer Logic Programing System and was mounted in a 7-by-35-foot testing van which was parked on the school grounds.

## PROCEDURE

All experimental procedures were administered in the testing van. The children were brought to the van by the experimenter in groups of three for testing, in pairs for training. The order in which the children came to the van each day for training was varied, although the pairs of children were generally drawn from the same classes.

PHASE 1 (Pretest, December 1974). All subjects were initially administered a match-to-sample letter discrimination test. Sample problems are presented in Figure 1. This test consisted of 22 match-to-sample problems: 5 letterlike forms used in training, 5 novel letterlike forms, 6 upper-case and 6 lower-case printed letters. Each problem contained a sample and 16 choices. The number of identical alternatives varied from one to five, with a mean of three for each problem. Subjects were told to "circle all of the shapes, just like the one at the top." Because the children worked slowly and became restless after several minutes, the test was administered over three consecutive days. At the

FIGURE 1. Sample Problems from the Paper-  
and-Pencil Match-to-Sample Test.

±

±	±	Λ	Λ	±	⊖	±	Λ
±	±	Λ	±	⊖	±	±	±

q

p	a	d	q	o	b	q	h
g	p	b	d	q	g	p	q

M

X	H	K	Z	A	N	E	M
K	H	M	X	W	A	W	N

end of each session, each child received a choice of several M&M's or a penny candy.

PHASE 2 (Machine Pretest, December 1974). Following completion of the paper-and-pencil pretest the children in the treatment group were brought to the van in pairs and individually taught to "work" the Human Test Console. While one child was given paper and crayons and allowed to draw, the other child sat in a chair in front of the Human Test Console. A curtain separated the children. The child was told to look at the shape in the center (a circle) and then to push the illuminated button (orienting key) to the left of the display panel. When the child did this, the orienting key went dark and the slide tray advanced to present the child with three choice stimuli, one in each panel. The child was told to look at each shape carefully and to push the one that was like the shape he had just seen. If the child chose correctly, the light above the tray was illuminated and a tone sounded for 1.5 seconds. Simultaneously the M&M feeder was activated and an M&M fell into the dish while the slide tray advanced to the next sample and the orienting key illuminated. The child was told he had picked the right one and that every time he made a correct choice he would receive an M&M. If the child pushed an incorrect panel, the slide tray simply advanced to the next sample. The child was told he had picked a shape that was not the same as the one he had seen and that if he had picked the correct choice he would have gotten an M&M. Five

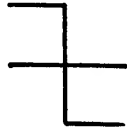


match-to-sample problems of geometric shapes were used to train the children to work the machine. Once each child correctly matched all five problems, he was then administered a match-to-sample test on the machine. Half of the test was given one day, and half, the following day. This "machine" test was composed of 46 three-choice match-to-sample problems of real letters and letterlike forms. Each problem contained an identical match, an alternative differing from the sample by one distinctive feature, and an alternative differing from the sample by more than one distinctive feature. Each child was given the M&M's he had earned at the end of the session. Several sample problems are presented in Figure 2.

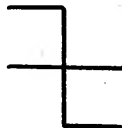
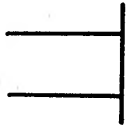
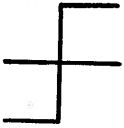
PHASE 3 (Treatment, December 1974 to February 1975). Training was begun the day after the completion of pretesting. Training lasted for 8 weeks, 5 days a week including a 2-week vacation after the first week. In all, the training series required over 700 correct matches. Each daily session required that each subject make 26 correct matches.

The match-to-sample training procedure was similar to the machine pretest, but with two additions. An incorrect response resulted in a brief time out, with the darkening of the display panel followed by a back-up procedure which repeated the problem the child had missed. The back-up procedure was programmed to repeat itself until the child made the correct response. When the child did respond correctly following an error, he was

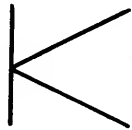
FIGURE 2. Sample Problems from the Machine  
Match-to-Sample Test.



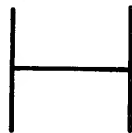
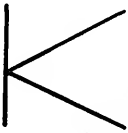
SAMPLE



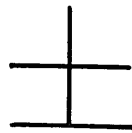
CHOICES



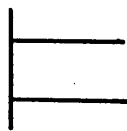
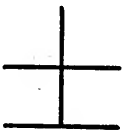
SAMPLE



CHOICES



SAMPLE



CHOICES

presented with the light, tone, and next stimulus, but no M&M.

Figure 3 provides a verbal summary of the programmed match-to-sample procedure.

The first time each child made an incorrect response in the training series, he was told he had picked the wrong one and would have to wait to try again. An initial time out of 10 seconds proved to be too long to maintain attention. Therefore, on the second day of training the time out was reduced to 3.5 seconds and maintained at that duration for the remainder of training.

The subjects were awarded M&M's each time they made a correct response during pretesting. A fixed ratio 2 was instituted during the first day of training. Subjects were told they would receive an M&M for each two correct matches. During the second week of training, a fixed ratio 3 was instituted, and the children were told they would receive an M&M each time they made three correct responses in a row. An incorrect response reset the ratio to zero. Subjects were also given the choice of keeping the M&M's they earned or trading them at the end of the session for a piece of penny candy. This arrangement was maintained for the remainder of the training sessions. Subjects had the option of eating their candy immediately after their session or of saving it for lunch time or after school. A clear plastic guard prevented the children from handling the M&M's during the sessions. The penny candy rewards were kept in a plastic box on a shelf behind the subjects. The box, but not the candy, was

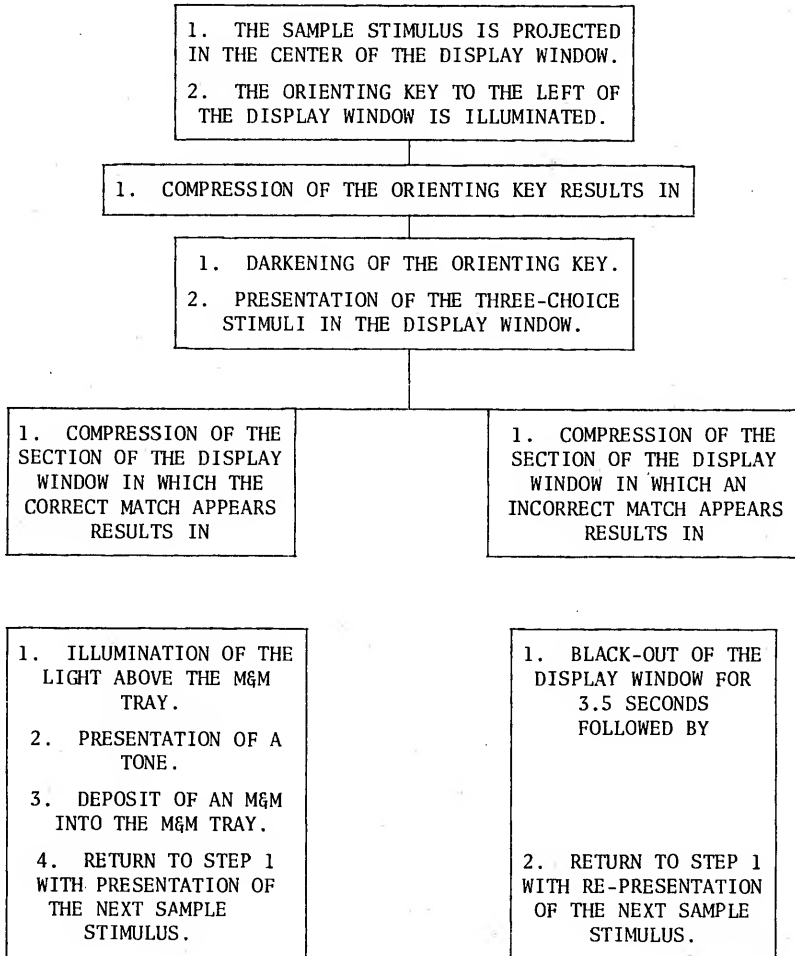


FIGURE 3. Summary of the Machine Match-to-Sample Paradigm.

visible during the training session. Daily sessions generally were 3 to 5 minutes in length.

The experimental group was administered distinctive feature training. A distinctive feature manifest in three different forms was emphasized during each session. The series was faded so that the distinctive feature was exaggerated in the first match of each form, while each succeeding match in the sequence presented a gradually diminishing difference between the forms. The faded sequence was designed so that the initial discrimination was easily made by all children while each succeeding discrimination was progressively more difficult. Figure 4 presents an example of a faded sequence for each distinctive feature. The three basic forms were alternated in the sequence to maximize perceptual scanning for the feature necessary to make the discrimination. The sequence in which the distinctive features were presented is provided in Table 1. Ten of the training series contain letterlike forms, and seven contain real letters, in order to evaluate the effect of training on both training and novel forms, independent of classroom experience with real letters. Figure 5 presents the training and novel forms.

The treated comparison group made the same matches in the same order as the experimental group, but the comparison stimuli differed from the sample by more than one distinctive feature. The comparison stimuli for any particular daily series included the comparison stimuli of the other two forms in the equivalent

FIGURE 4. A Faded Sequence for Each  
Distinctive Feature.

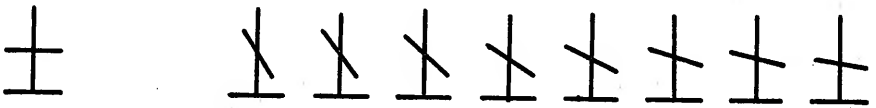
## CLOSE VERSUS BREAK



## CURVE VERSUS STRAIGHT



## ANGULARITY



## ROTATION



## REVERSAL

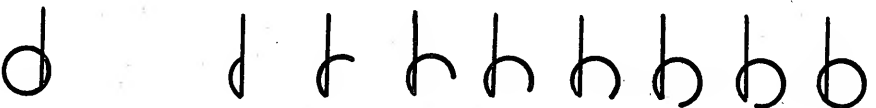




TABLE 1. Sequence of Presentation of Distinctive Features.

<i>Day</i>	<i>Distinctive Feature</i>	<i>Type of Forms</i>
1	Close versus break	Artificial
2	Angularity	Artificial
3	Curve versus straight	Artificial
4	Rotation	Artificial
5	Reversal	Artificial
6	Close versus break	Artificial
7	Angularity	Artificial
8	Curve versus straight	Artificial
9	Rotation	Artificial
10	Reversal	Artificial
11	Additional feature	Real letters
12	Close versus break	Real letters
13	Angularity	Real letters
14	Curve versus straight	Real letters
15	Rotation	Real letters
16	Reversal	Real letters
17	Reversal	Real letters
18	Close versus break	Repeat-artificial
19	Angularity	Repeat-artificial
20	Curve versus straight	Repeat-artificial
21	Rotation	Repeat-artificial
22	Reversal	Repeat-artificial
23	Close versus break	Repeat-real letters
24	Curve versus straight	Repeat-real letters
25	Rotation	Repeat-real letters
26	Reversal	Repeat-real letters

FIGURE 5. Basic Training and Novel  
Letterlike Forms.

## TRAINING FORMS

p 7

F d

± €

h z

L 7

y W

## NOVEL FORMS

d C

L o

I €

K C

K 2

distinctive feature series. Thus, the stimuli presented to both groups were identical. Both groups made the same matches, in the same order; only the incorrect choices differed for each group on any particular discrimination. Thus, it was necessary to respond to a single distinctive feature in the experimental group and to multiple differences in the treated comparison group. Figure 6 presents corresponding sample problems for the experimental and treated comparison groups.

The control group received only classroom experience during Phase 3.

PHASE 4 (Machine Posttest, February 1975). Following the completion of the training series, the treatment group was re-administered the match-to-sample letter discrimination test as described in Phase 2.

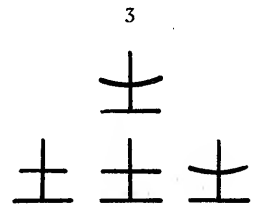
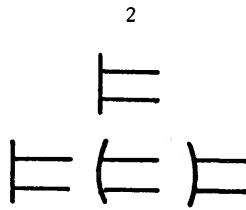
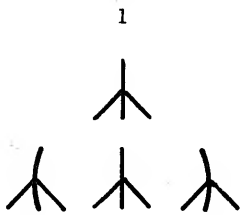
PHASE 5 (Probe 1, February 1975). Children in both the treatment and control groups were readministered the paper-and-pencil match-to-sample test as described in Phase 1. This post-test shall be referred to as Probe 1.

The treatment group was then given 8 weeks training in grapheme-phoneme associations by another experimenter (Fitzsimmons, 1975).

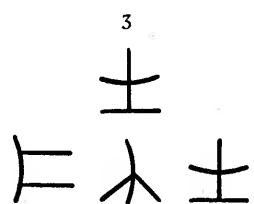
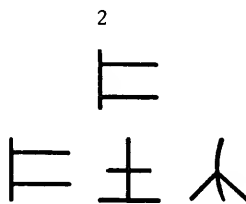
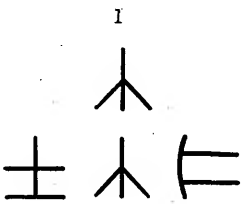
PHASE 6 (Probe 2, May 1975). Three months following the end of Phase 3 (letter discrimination training), subjects in the treatment and control groups were again administered the paper-and-pencil match-to-sample test described in Phase 1. In addition

FIGURE 6. Corresponding Match-to-Sample Problems for the Experimental and Comparison Groups--Curve versus Straight Feature.

## EXPERIMENTAL



## COMPARISON



to this test, the children were administered the Beery Test of Visual Motor Integration (a screening battery subtest) and teacher ratings were obtained. Teachers were asked to rate each child on scales related to achievement group, ability to recite, recognize, and write letters on command, and ability to write name. Teachers were also asked to rate each child's attention span and to predict whether each child would or would not have a reading problem. The questions included in the questionnaire are presented in Table 2. The data obtained during the 3-month follow-up shall be referred to as Probe 2.

PHASE 7 (Probe 3, February 1976). One year following the end of training, the children in the treatment and control groups were readministered the paper-and-pencil match-to-sample test as described in Phase 1. In addition to this test, the children were also administered the Beery Developmental Test of Visual-Motor Integration (Beery & Buktenica, 1967), a word matching subtest of the Clymer-Barrett Prereading Battery (Clymer & Barrett, 1967), and the Iota Word Test (Monroe, 1932). The Beery requires the child to copy graphic designs of increasing complexity. The Clymer-Barrett word matching subtest requires the child to select a word from a group of four that is identical to the sample word. For example, *pan* appears on the left as the sample word, followed by the choices *nap*, *pin*, *pan*, and *ban*. The Iota is a word recognition test which requires the child to pronounce increasingly more difficult words. Also,

TABLE 2. Sample Questions from Kindergarten and First-Grade Teacher Questionnaires.

Kindergarten Student Achievement Questionnaire

Please rate \_\_\_\_\_ on the following dimensions without regard to your knowledge of this student's participation in any special program.

Was this student originally assigned to a (1) superior, (2) average, (3) below average achievement-learning group?

Is this student presently working in a (1) superior, (2) average, (3) below average achievement-learning group?

Is this child able to recite (1) all, (2) most, (3) approximately half, (4) few, (5) none of the lower-case letters of the alphabet.

Is this child able to write his/her name? Yes--no.

Is this child able to write on command (1) all, (2) most, (3) approximately half, (4) few, (5) none of the letters of the lower-case alphabet?

Is this child able to recognize by naming (1) all, (2) most, (3) approximately half, (4) few, (5) none of the lower-case letters of the alphabet?

Does this child, in your opinion, have a (1) good, (2) average, (3) poor attention span?

Do you think this child has or will have a reading problem? Yes--no.

First-Grade Achievement Questionnaire

Please rate \_\_\_\_\_ on the following dimensions:

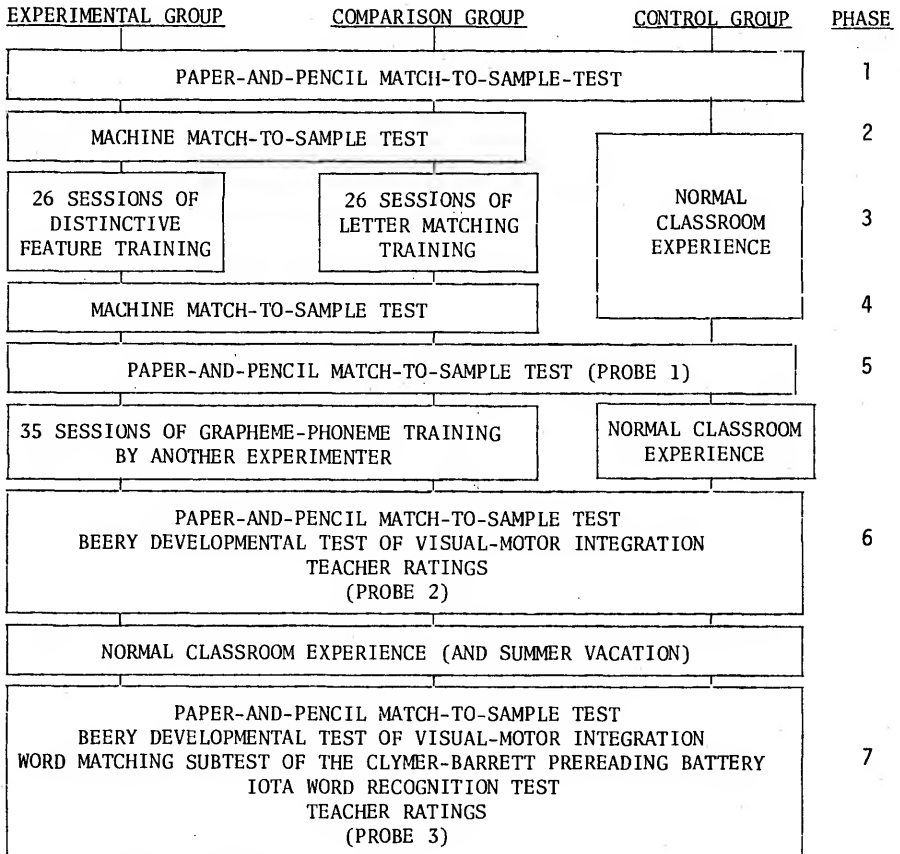
Is this student presently working in a (1) superior, (2) average, (3) below average achievement-learning group?

Do you think this child has or will have a reading problem? Yes--no.



teacher ratings of achievement level and prediction of reading problems were again obtained. The one-year follow-up shall be referred to as Probe 3.

Twenty of the 24 children comprising the treatment and control groups were enrolled in county schools and were included in Probe 3. The remaining children could not be located. A flow chart of the complete procedure is presented in Figure 7.



NOTE: Phase 1, December 1974; Phase 2, December 1974; Phase 3, December 1974 to February 1975; Phase 4, February 1975; Phase 5, February 1975; Phase 6, May 1975; Phase 7, February 1976.

FIGURE 7. Flow Chart of Experimental Procedure.

### III RESULTS

PREVENTION RESEARCH PRESENTS a unique problem in assessing the effects of treatment. The proportion of false positives in the target population must be considered. Data from Satz, Friel, and Rudegeair's (1975) original validation study using third-year reading level as the criterion measure reveal that 82% of children classified as high risk for severe reading difficulties indeed exhibited reading difficulties in third grade, while 18% were average readers (false positives). Applying this data to the present sample, one would expect that approximately 18% of the high risk children would actually become average readers without treatment. This would equal four to five children in the combined treatment and control groups.

Teacher ratings at the end of kindergarten (Probe 2) and in the middle of first grade (Probe 3) were examined in order to identify and eliminate apparent "false positives" from the data analysis. Table 3 presents the teacher ratings dichotomized to reflect above and below average performance. Subjects are ranked according to the proportion of above and below average ratings. Three children in the control group were expected by their

TABLE 3. Teacher Ratings Dichotomized to Show Above (+) and Below (0) Average Performance.

Read. Prob.	Ach. Grp.	Read. Prob.	Ach. Grp.	Alph. Write Prob.	Alph. Recog. Prob.	Alph. Recit. Prob.	Write Name Prob.	Att. Span Prob.
2	2	3	3	2	2	2	2	2
TREATMENT GROUP								
1C*	0	0	0	0	0	0	0	0
2E	0	0	0	0	0	+	+	0
3C	0	0	0	0	+	0	+	0
4C	0	0	0	0	0	0	+	+
5E	0	0	0	0	0	0	+	+
6C	0	0	0	0	0	0	+	0
7E	+	0	0	0	0	+	0	+
8E	0	+	0	0	+	+	+	0
9C	0	+	0	0	+	+	+	+
10E	+	+	+	0	+	+	+	+
11E	+	+	0	0	+	+	+	+
12E	+	+	0	0	+	+	+	0
13C	+	+	0	+	+	+	+	+
CONTROL GROUP								
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	+	0
4	0	0	0	0	0	0	0	+
5	0	0	0	0	0	+	+	0
6	+	0	0	0	0	0	+	0
7	+	0	0	0	0	+	+	+
8	0	+	+	0	0	0	+	0
9	+	+	+	+	+	+	+	+
10	+	+	+	+	+	+	+	+
11	+	+	+	+	+	+	+	+

\* E = experimental group and C = comparison group.

kindergarten and first-grade teachers to become average readers and were clearly classified as performing at an average or above average level in kindergarten and first grade. Three children in the treatment group also met these criteria. However, since the treatment was designed to affect reading performance, the number of "false positives" in the treatment group would be predicted to increase as a result of treatment. Therefore, teacher ratings of the original achievement level of each child, as well as performance on the screening battery itself, were considered in eliminating "false positives" from the treatment group. These data provide indications of pretreatment performance levels. Table 4 presents the original achievement level ratings and screening battery performances dichotomized to reflect above and below average performance. Only two of the six potentially false positive subjects were rated by their kindergarten teachers as performing in the average range at the beginning of the school year. However, all three of the false positive subjects in the control group performed in the average range on more than half of the screening battery subtests, while only one of the potentially false positive subjects in the treatment group did so. Since this subject was also the only subject in the treatment group whose original classroom performance had been in the average range, this subject was eliminated from the data analysis. The other two subjects were retained because their pretreatment performance was below average. The identification

TABLE 4. Screening Battery Performances and Teacher Ratings of Pretreatment Achievement Levels Dichotomized to Show Above (+) and Below (0) Average Performance.

Teacher Rating Orig. Ach. Level Probe 2	S C R E E N I N G   B A T T E R Y									
	Alph. Recit.	Peab. Pict. Voc.	Recog. Discri.	Finger		Beery		Aud. Discri.	Dich. List.	
				Local.	V-M	Integ.	Test			
TREATMENT GROUP										
1	0	0	0	0	0	0	0	0	+	
2	+	0	0	0	0	0	0	0	0	
3	0	0	+	0	0	0	0	0	0	
4	0	0	+	0	0	0	0	0	0	
5	0	+	0	0	0	0	0	0	+	
6	0	0	+	+	0	0	0	0	+	
7	+	0	+	0	0	0	0	+	0	
8	+	0	0	+	0	0	0	0	+	
9	0	+	0	0	0	0	0	+	0	
10	+	0	0	+	+	+	+	0	0	
11	0	0	0	+	+	+	+	+	+	
12	+	+	0	+	+	+	+	+	+	
13	0	+	0	0	0	0	0	0	0	
CONTROL GROUP										
1	0	+	0	0	0	0	0	0	+	
2	0	0	0	0	0	0	0	0	0	
3	0	0	0	+	0	0	0	0	+	
4	0	0	+	0	0	0	0	0	+	
5	0	0	0	0	+	0	0	0	+	
6	0	+	0	0	0	+	0	0	0	
7	0	0	0	0	0	0	0	0	+	
8	0	0	0	0	0	0	0	0	0	
9	+	0	0	+	0	0	0	0	0	
10	+	0	0	0	0	0	0	+	+	
11	0	+	0	0	0	0	0	+	+	

of four "false positives" from the two groups is within the range of four to five predicted by the original validation study. The elimination of these subjects leaves an experimental group of  $N=6$ , comparison group of  $N=6$ , and control group of  $N=8$ .

A Kruskal-Wallis One-Way Analysis of Variance by Ranks was used to analyze all data comparing the experimental, comparison, and control groups, while a Mann-Whitney U-Test was used to analyze all data comparing only two groups. Analysis of teacher ratings was done using the Fisher Exact Probabilities Test.

#### MACHINE MATCH-TO-SAMPLE TEST

The mean number of incorrect matches on the match-to-sample machine pretest was 17 (range 5-31) for the experimental group ( $N=6$ ) and 19.6 (range 11-32) for the comparison group ( $N=6$ ). These scores were not significantly different ( $U=14$ ,  $p \leq .294$ ). On the machine posttest the mean number of incorrect matches was 9.1 (range 5-13) for the experimental group ( $N=6$ ) and 10.5 (range 8-14) for the comparison group ( $N=6$ ). Again, these scores were not significantly different ( $U=14.5$ ,  $p \leq .294$ ). Thus, no differential effect was present for distinctive feature training versus letter discrimination training on the match-to-sample machine posttest.

## PAPER-AND-PENCIL MATCH-TO-SAMPLE TEST

PRETEST. Both confusion errors and correct matches were scored on the match-to-sample letter discrimination test. The mean number of confusion errors on the pretest was 13.6 (range 5-28) for the experimental group ( $N=6$ ), 16.6 (range 7-28) for the comparison group ( $N=6$ ), and 17.5 (range 1-34) for the control group ( $N=8$ ). Pretest error scores did not differ significantly among these three groups ( $H=.69$ ,  $p \leq .80$ ). The mean number of errors for the superior group ( $N=13$ ) was 1.8 (range 1-4). The scores of the superior group differed significantly from those of the combined high-risk groups ( $U=8$ ,  $p \leq .001$ ).

The mean number of correct matches made on the pretest was 60.8 (range 43-67) for the experimental group, 56.5 (range 29-68) for the comparison group, and 60 (range 50-69) for the control group. Pretest correct scores did not differ significantly among these three groups ( $H=.70$ ,  $p \leq .80$ ). The mean number of correct matches for the superior group was 65.6 (range 56-68). The scores of the superior group differed significantly from those of the combined high-risk groups ( $U=60$ ,  $p \leq .01$ ). These results confirm that no difference among the high-risk groups on the letter matching test were present prior to training. Comparisons with the superior group demonstrate that the test does discriminate predicted above and below average readers.



PROBE 1. The mean number of confusion errors on the posttest (Probe 1) was 7.1 (range 2-25) for the experimental group ( $N=6$ ), 8.3 (range 3-17) for the comparison group ( $N=6$ ), and 9.5 (range 3-24) for the control group ( $N=8$ ). These scores were not significantly different ( $H=2.74$ ,  $p<.30$ ), although the scores do represent a trend in the predicted direction. A survey of pretest scores indicated that only one of the high-risk children, a control subject, fell within the range of the superior group, while posttest scores indicated that 67% of the experimental subjects, 17% of the comparison subjects, and 25% of the control subjects fell within the superior range. These percentages represent a trend in the predicted direction, although this finding is not significant (Fisher Test,  $p>.05$ ).

The mean number of correct matches on the posttest was 63.3 (range 59-69) for the experimental group, 61.5 (range 51-68) for the comparison group, and 59.3 (range 46-65) for the control group. These scores were not significantly different ( $H=1.36$ ,  $p<.70$ ). These results demonstrate the absence of a clear treatment effect, although there appears to be a reduction in confusion errors in the predicted direction for the experimental group.

TRAINING VERSUS NOVEL FORMS. The mean number of pre and posttest confusion errors for training and novel forms was also calculated. The mean number of errors on pretest training forms was 4.8 (range 1-11) for the experimental group, 7.1 (range 3-12)

for the comparison group, and 7.6 (range 0-20) for the control group. These scores were not significantly different ( $H=.79$ ,  $p \leq .70$ ). The mean number of errors on pretest novel forms was 5.1 (range 1-10) for the experimental group, 4.8 (range 3-9) for the comparison group, and 6.0 (range 1-10) for the control group. These scores were not significantly different ( $H=4.55$ ,  $p \leq .20$ ). The mean number of errors on posttest training forms was 2.5 (range 0-10) for the experimental group, 4.3 (range 2-8) for the comparison group, and 4.0 (range 0-9) for the control group. These scores were not significantly different ( $H=3.00$ ,  $p \leq .30$ ). The mean number of errors on posttest novel forms was 3.6 (range 1-10) for the experimental group, 3.0 (range 1-8) for the comparison group, and 3.3 (range 0-9) for the control group. These scores were not significantly different ( $H=.05$ ,  $p \leq .98$ ). Thus, no differences were apparent among the groups in the number of errors made on training or novel forms following training.

PROBE 2. The mean number of errors on the 3-month follow-up (Probe 2) was 7.6 (range 1-25) for the experimental group ( $N=6$ ), 10.3 (range 2-20) for the comparison group ( $N=6$ ), and 10.1 (range 2-21) for the control group ( $N=7$ ). These scores were not significantly different ( $H=1.46$ ,  $p \leq .50$ ). However, 67% of the experimental group continued to score in the superior range, while only 33% of the comparison group and 28% of the control group scored in the superior range.

The mean number of correct matches on the 3-month follow-up was 59.1 (range 55-62) for the experimental group, 62.3 (range 57-67) for the comparison group, and 59.1 (range 49-69) for the control group. These scores were not significantly different ( $H=1.70$ ,  $p \leq .50$ ). Although no latent treatment effect in letter matching performance was apparent 3 months following treatment, the finding of an increased number of experimental subjects performing in the superior range for letter confusions continued to be present.

PROBE 3. The mean number of errors on the one-year follow-up (Probe 3) was 5.1 (range 1-8) for the experimental group ( $N=6$ ), 4.7 (range 3-6) for the comparison group ( $N=4$ ), and 6.1 (range 1-15) for the control group ( $N=7$ ). These scores were not significantly different ( $H=.11$ ,  $p \leq .95$ ). A survey of scores indicated that 33% of the experimental group, 25% of the comparison group, and 57% of the control group performed in the superior range.

The mean number of correct matches on the one-year follow-up was 63.6 (range 59-67) for the experimental group, 64.7 (range 58-69) for the comparison group, and 65.1 (range 57-70) for the control group. These scores were not significantly different ( $H=.72$ ,  $p \leq .70$ ). No differences in confusion errors or correct matches were present one year following letter discrimination training. The tendency for more experimental subjects to perform in the superior range was no longer present one year following training.

Figure 8 presents the mean confusion errors for each group plotted across probes, while Figure 9 presents the mean number of correct matches for each group plotted across probes. It should be noted that at no time do any of the mean high-risk scores equal or exceed the mean pretest scores of the superior group, even on the one-year follow-up.

### THREE-MONTH FOLLOW-UP (PROBE 2)--TEACHER RATINGS

Teacher ratings taken at the end of kindergarten were dichotomized, cast into a 2-by-2 contingency table, and analyzed using the Fisher Exact Probabilities Test. Since the purpose of the teacher ratings was to assess the effects of the combined letter discrimination and grapheme-phoneme training, the experimental and comparison groups were combined in this analysis.

The treatment and control groups did not differ significantly on ratings of original achievement-learning group, present achievement-learning group, alphabet recitation, ability to write the alphabet on command, ability to write the child's own name, attention span, and prediction of reading problem. The children in the treatment group, however, were rated by their teachers as performing significantly better than the control group at *recognizing* letters of the alphabet ( $p < .025$ ).

FIGURE 8. Mean Confusion Errors on the  
Paper-and-Pencil Match-to-Sample Test  
Plotted Across Probes for the Experimental  
(●), Comparison (●), Control (●), and  
Superior (⊗) Groups.

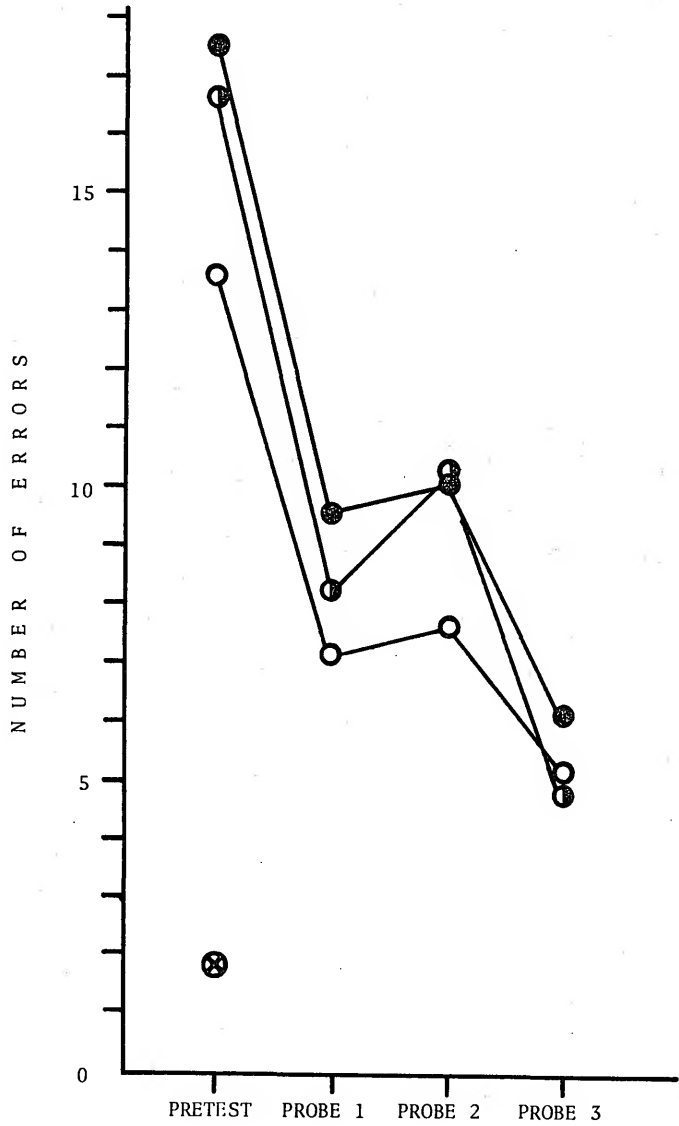
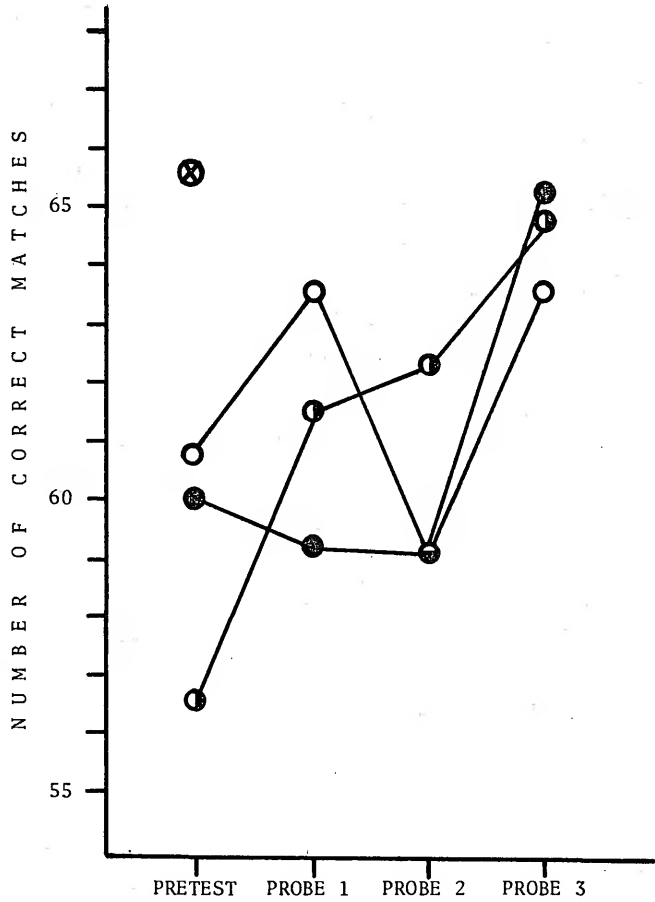


FIGURE 9. Mean Correct Matches on the Paper-and-Pencil Match-to-Sample Test Plotted Across Probes for the Experimental (○), Comparison (●), Control (◐), and Superior (⊗) Groups.





## ONE-YEAR FOLLOW-UP (PROBE 3)--OBJECTIVE MEASURES AND TEACHER RATINGS

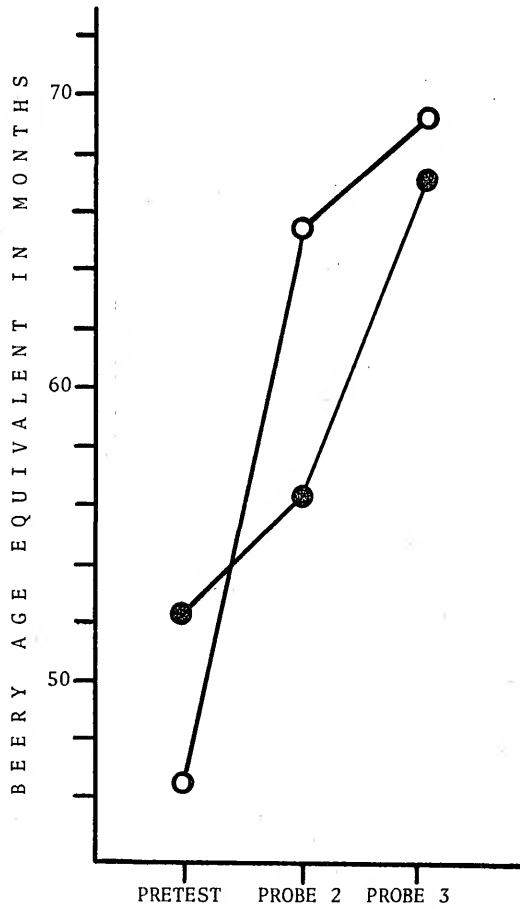
In addition to the match-to-sample test already discussed, the word-matching subtest of the Clymer-Barrett Prereading Battery was included in Probe 3 in order to guard against ceiling effects on the letter matching test. The Iota Word Recognition Test was also included as an objective measure of beginning reading ability. The mean number of confusion errors on the word-matching test was 5.2 (range 0-17) for the treatment group ( $N=10$ ) and 5.7 (range 3-10) for the control group ( $N=7$ ). These scores were not significantly different ( $U=24.5$ ,  $p>.05$ ). The mean number of correct pronunciations on the word recognition test was 3.5 (range 0-9) for the treatment group and 1.4 (range 0-10) for the control group. These scores were not significantly different ( $U=19$ ,  $p>.05$ ).

## BEERY TEST OF VISUAL-MOTOR INTEGRATION

The Beery Test of Visual Motor Integration was included in Probes 2 (kindergarten level) and 3 (first grade) because of changes reported by school personnel on this measure in their treatment group. Pretraining scores were available because the Beery is one of the tests included in the screening battery. The mean pretraining score in months was 46.6 (range 34-60) for the experimental group ( $N=12$ ) and 52.1 (range 34-67) for the control group ( $N=8$ ). These scores were not significantly different ( $U=38$ ,  $p>.05$ ). The mean score at Probe 2 (8 months later) was 65.5 (range 57-82) for the experimental group ( $N=11$ ) and 56.3

(range 46-63) for the control group ( $N=6$ ). These scores differed significantly in the predicted direction ( $U=15$ ,  $p \leq .05$ ). This represents an average increase of 18.9 months for the treatment group and 4.2 months for the control group. The mean difference between chronological age and Beery age equivalent on the pre-training administration was 12.5 months for the treatment group and 9.9 for the control group. At Probe 2, however, the difference was 2 months for the treatment group and 13.7 for the control group. The mean score at Probe 3 (16 months after the initial testing) was 69.2 months for the experimental group and 67.2 months for the control group. These scores were not significantly different ( $U=27$ ,  $p > .05$ ). The mean difference between chronological age and Beery age equivalent was 6.3 for the treatment group and 10.8 for the control group. Figure 10 presents the mean scores in months plotted across probes. These data suggest that the combined grapheme and grapheme-phoneme training resulted in a substantial improvement in visual-motor performance. Furthermore, it would appear that the effect obtained from treatment was not retained 9 months later.

FIGURE 10. Mean Beery Age Equivalents in  
Months Plotted Across Probes for the  
Treatment (O) and Control (●) Groups.



## IV DISCUSSION

ONE PURPOSE OF THIS EXPERIMENT was to evaluate two methods of letter discrimination training with children predicted to have severe reading difficulties. The goal of treatment was to improve letter discrimination performance by reducing confusion errors. Hypotheses I, II, III, and V specifically relate to improving letter discrimination performance. Hypothesis I was not confirmed. No differences in confusion errors were present for the "distinctive feature group" versus "letter discrimination group" on the "machine" match-to-sample posttest. However, both groups reduced their mean number of errors by almost one half. Hypotheses II, III, and V also were not confirmed. No differences in either confusion errors or correct matches were present for the experimental, comparison, and control groups on the paper-and-pencil match-to-sample test immediately, 3 months, or one year following discrimination training. However, all groups reduced their mean number of errors by almost one half in the 2-month period between pretesting and posttesting. It is interesting that confusion errors did not decrease over the next 3-month period, which covered the remainder of the school year, but did decrease moderately over the next 9-month period, which included

summer vacation and the initial half of first grade. Even in the middle of first grade the "high risk" group continued to average more confusion errors than the "superior" group had in early kindergarten.

The pattern of change for number of correct matches across the four probes was less consistent and smaller for the three groups than was the pattern of change of error responses. The control group showed no change in mean number of correct responses on the pretest, posttest, and 3-month follow-up, but then improved almost enough from Probe 2 to Probe 3 to equal the superior group pretest performance. The experimental group showed an initial improvement on the posttest, then a regression on Probe 2, and finally matched their posttest performance on the one-year follow-up. The comparison group showed an initial sharp increase in correct matches, followed by a flattening out between the posttest and 3-month follow-up and then a slight increase again at Probe 3. All three groups approached the mean pretest performance of the superior group on the one-year follow-up.

These results suggest that neither the faded distinctive feature training nor the more traditional multiple-feature discrimination training were more effective than regular classroom teaching in improving letter discrimination performance. The lack of differences in errors on training and novel forms across the three groups further substantiates this conclusion. It is unclear to what extent the pattern of changes in scores across

probes is the result of repeated testing, maturation, and actual classroom experience. It does seem quite possible that the greater amount of class time spent each day on the alphabet and prereading skills may have overshadowed or "washed-out" the effect of very brief, daily treatment sessions.

One shortcoming of the present experiment is that the very small number of subjects in each group allows only very simple statistical analyses requiring clear differences in order to reach significance. This is an important consideration in prevention research because success might better be represented by the increase in proportion of high risk subjects performing in the normal range, rather than simply by a demonstration of a statistically significant increase in scores. In regard to letter confusions, it was found that two thirds of the distinctive feature group versus less than one fourth of the comparison and control groups performed in the "superior group" range immediately following training. This trend was visible 3 months following training: two thirds of the experimental group continued to perform in the superior range, while less than one third of the comparison and control groups did so. However, this trend was not apparent one year following discrimination training. Although this effect is not statistically significant, it does suggest that an increased proportion of experimental subjects may have performed in the "superior range" on the paper-and-pencil match-to-sample test as a result of distinctive feature training.

Another purpose of this experiment was to evaluate the effect of an intervention program combining letter discrimination training and grapheme-phoneme training on reading related performances. Hypotheses IV, VI, VII, and VIII relate to reading related performances. Hypothesis IV, for the most part, was not confirmed. No significant differences between the treatment and control groups were present immediately following grapheme-phoneme training on teacher ratings of overall achievement, ability to recite or print the alphabet, ability to print own name, and attention span. No differences between the treatment and control groups were present for teacher predictions of the presence or absence of a reading problem for each child. However, significantly more treatment than control children were judged by their teachers as being able to recognize most of the letters of the alphabet. This is not surprising if one considers that treatment is more directly related to this measure than any of the others. Hypothesis VIII relates to teacher ratings taken 9 months after the termination of grapheme-phoneme training. No differences were present on ratings of overall achievement in the middle of first grade nor were any differences noted in the proportion of children in each group predicted to develop a reading problem.

Hypotheses VI and VII relate to two objective measures administered 9 months after the end of combined treatment. Hypothesis VI was not confirmed. No differences were apparent



between children in the treatment and control groups on the Clymer-Barrett word matching subtest. This test was included at Probe 3 in order to guard against a possible ceiling effect on the paper-and-pencil match-to-sample test, since the word-matching test was composed of confusing letter sequences rather than single confusing letters, and letter sequences are generally more difficult to discriminate than single letters. However, the directions allowed for only one choice in each match-to-sample problem. Many of the children initially circled several choices, but when required to choose only one, they inevitably chose the identical match and eliminated the similar but not identical alternatives. This is consistent with Caldwell and Hall's (1969) observation that letter confusions do not result from perceptual or attentional deficits, but rather from differences in children's concept of same/different. The large number of correct matches made throughout the match-to-sample letter discrimination test also tends to support this conclusion.

Hypothesis VII was not confirmed. No differences were present 9 months after combined letter discrimination and grapheme-phoneme training on the Iota word recognition test. Considered together, these results suggest that letter discrimination and grapheme-phoneme training had little effect on teacher ratings of children's academic performance or on several objective measures of reading related skills, either immediately following training or 9 months later.

Dramatic differences were apparent on only one measure: the Beery Test of Visual-Motor Integration. The treatment group scored a year below its chronological age on the original administration, while the control group scored almost 10 months below age expectancy. Following training, the treatment group scored only 2 months below their chronological age, while the control group scored over a year below age expectancy. This represents an average increase of over a year and a half for the treatment group but only 4 months for the control group. Although the treatment group remained only 6 months below age expectancy 9 months following treatment, while the control group continued to be over 10 months below age expectancy, performances were not significantly different at this time. These results suggest that letter discrimination and grapheme-phoneme training significantly improved Beery visual-motor performance, although the effect appears to have been temporary.

The discovery of a treatment effect on the Beery Test of Visual Motor Integration highlights a potential difficulty of prevention research. Although it is not unreasonable that training in visual discrimination would effect visual-motor functioning, it is surprising to register such a dramatic effect on a measure indirectly related to training when an absence of effect was seen on more direct measures. This supports the observation that experimental treatments may often have effects not predicted or intended by the experimenter. Such peripheral

effects can be as important, pragmatically, as the evaluation of main effects.

A particular difficulty exists in prevention research where an attempt is made to affect a behavior before it has appeared developmentally. One of the purposes of this study was to improve reading skills, with the goal of reducing the proportion of children eventually performing below grade level in reading. Treatment was administered to subjects predicted to develop reading difficulties before they had in fact begun to learn to read. After treatment it is difficult to differentiate false positive subjects (those who would be average readers without treatment) from valid positive subjects who are in fact average readers as a result of treatment. In the present experiment a broader assessment of each child's academic functioning prior to treatment, in the form of teacher ratings and readiness tests, may have helped to differentiate false positive and valid positive subjects following treatment. This is particularly important when for practical reasons the number of subjects must remain small. Studies using large numbers of subjects in combination with accurate conditional probabilities of false and valid positive rates would also minimize this problem.

The results of this experiment suggest that a broad range of related skills in the form of independent criterion measures should be assessed prior to and following treatment, in order to differentiate false and valid positive subjects, as well as to

more extensively sample the effects of treatment. The present results indicate that a skill indirectly related to treatment showed improvement while skills more directly related to treatment appeared unaffected. The importance of follow-up probes was also supported. While improvement in visual-motor performance was present immediately following training, no differences were present between treatment and control groups 9 months later.

In summary, distinctive feature and letter discrimination training did not appear to be any more effective than regular classroom experience in reducing letter confusions and increasing correct letter matching. Furthermore, combined letter discrimination and grapheme-phoneme training did not appear to affect teacher ratings of reading related classroom performance, except that more treatment than control children were rated as recognizing more than half the letters of the alphabet. Children in the treatment group performed significantly better than those in the control group on the Beery Test of Visual Motor Integration immediately following training, but the difference was not present 9 months later. No differences between treatment and control groups were apparent on word matching and word recognition tests 9 months following training.

Eighty-three percent of the high-risk children began kindergarten in the below-average learning group. At the end of kindergarten, 67% remained in the below-average learning group while 54%

were predicted by their teachers to develop reading difficulties. Half way through first grade, 70% of the high-risk children were performing below average academically while 75% were seen as having, or were predicted to develop, reading problems. The children included in this experiment began kindergarten far behind the majority of children their age on such diverse skills as visual-motor development, visual discrimination, auditory discrimination, somatosensory development, alphabet knowledge, and extent of vocabulary. These children represent a developmentally retarded sample of children. The vast majority of these children continued to perform far below the level of their peers in first grade. It seems reasonable to conclude that more intensive intervention may be required in order to produce dramatic effects.

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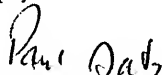
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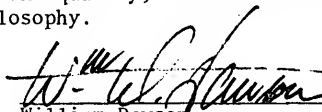
## BIOGRAPHICAL SKETCH

TERRY SHANNON PROEGER was born 9 May 1947, in Pittsburgh, Pennsylvania. He attended schools in Port Vue, Pennsylvania, and in June 1965 was graduated from Port Vue-Liberty High School. He received the degree of Bachelor of Arts from the University of Florida in June 1969, and in September of that year he began study in psychology at the University of Florida. He received the degree of Master of Arts from the University of Florida in June 1972.

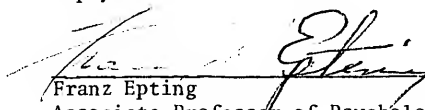
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Paul Satz, Chairman  
Professor of Clinical Psychology

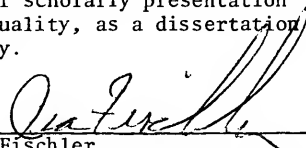
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Professor of Ophthalmology

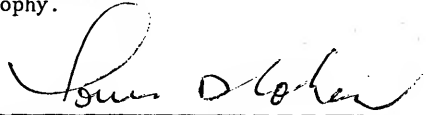
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Ira Fischler  
Assistant Professor of Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

A handwritten signature in cursive script, appearing to read "Louis Cohen", written over a horizontal line.

Louis Cohen  
Professor and Chairman  
of Clinical Psychology

This dissertation was submitted to the Graduate Faculty of the Department of Psychology in the College of Arts and Sciences and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

June 1976

Dean, Graduate School

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